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ENVIRONMENT

Subject
Summary of Meeting to Discuss Results of Groundwater Investigation
Lake Calumet Cluster Site, Chicago, Illinois

Date
December 22, 2017

Contact
Jack Kratzmeyer

Phone
312 575.3721

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Our ref
CI001805.00--

Dear Ms. Kolak:

This letter summarizes the key issues identified at the meeting among the U S. Environmental Protection Agency (USEPA), Illinois Environmental Protection Agency (IEPA), and representatives of the Lake Calumet Cluster Site (LCCS or Site) Group (the Group) on October 18, 2017. The purpose of the meeting was to provide an opportunity for the technical representatives of the Group to review with USEPA and IEPA the findings and conclusions from the recently completed Site groundwater investigations with the goals of establishing a collective understanding of Site conditions and developing an agreed path forward for completion of the Operable Unit 2 (OU2) Remedial Investigation (RI) and risk assessments. The results of the groundwater investigations were presented in the *Technical Memorandum on the Groundwater Assessment for Operable Unit 2 at the Lake Calumet Cluster Site* (Tech Memo) submitted to USEPA and IEPA by Arcadis on behalf of the Site Group on July 24, 2017 (Arcadis 2017)

Our overall takeaway from the meeting is that all parties have a similar appreciation that the LCCS is located in an area where industrial activity and waste disposal have impacted groundwater throughout the region for many years. The LCCS itself is a conglomeration of multiple waste handling and disposal locations adjacent to three other landfills. As a result of that historical regional activity, in many instances concentrations of constituents of concern (COCs) in groundwater entering the LCCS are higher than those in groundwater emanating from the Site.

In the meeting, USEPA and IEPA discussed technical issues that need to be addressed to complete the OU2 RI and risk assessments These issues are discussed in the following paragraphs and necessary proposed actions are outlined

Evaluation of Off-Site Groundwater

At the October 18, 2017 meeting, IEPA expressed its view that the LCCS is a hazardous waste landfill to which the groundwater monitoring requirements in the Illinois Part 724 regulations (35 IAC Part 724) would apply. IEPA further indicated that off-site groundwater monitoring might be required to determine the extent of groundwater offsite that exceeds the Class 2 standards.

As described in the Tech Memo, groundwater across the LCCS generally flows from the north and west to the south and east. North Indian Ridge Marsh lies just east of the Site, across the Norfolk Southern railroad right-of-way, and serves as a discharge zone for shallow groundwater on the eastern boundary of the Site. Groundwater on the southern boundary of the Site would discharge across 122nd Street to the south. Because there is a City-wide ordinance prohibiting private potable water supply wells, there are no potential receptors between LCCS and its surface water discharge locations. The OU2 RI will discuss local and regional groundwater hydrology and the fate and transport of groundwater emanating from the LCCS.

If the Illinois Part 724 regulations are determined to be potentially applicable or relevant and appropriate requirements (ARARs), the monitoring requirements will be incorporated into the remedial action alternatives evaluated in the FS. Based on available data and on the assessment presented in the Tech Memo, impacts to groundwater quality are present on a region-wide basis and the Group anticipates that characterization of area background conditions would be included as part of any groundwater monitoring program incorporated into remedial alternatives evaluated in the FS.

Evaluation of Deep Groundwater

Historical information suggesting that the native Dolton Sand may have been mined at the Site was confirmed by geologic observations during the soil boring sampling program. None of the soil borings for piezometer or monitoring well installation encountered native materials. The water-bearing zone beneath the Site is comprised of waste fill materials, and therefore, IEPA groundwater standards do not apply to on-site groundwater [1]

The shallowest native geologic unit at the Site is a low-permeability silty clay located immediately beneath the anthropogenic fill deposits. The silty clay unit was encountered at every soil boring location and extends to the maximum depth of all soil borings completed.

During the meeting, Paul Lake of the IEPA inquired about specific portions of the hydraulic profiling tool (HPT) logs presented in the Tech Memo, specifically regarding the silty clay unit. Mr. Lake interpreted several of the logs (including those for HPT-01, HPT-10, and HPT-10A) to suggest the presence of a relatively permeable zone atop the silty clay layer that serves as a regional barrier to vertical groundwater migration.

The appearance of a higher-permeability unit in these logs is an artifact of a pressure sensor failure within the HPT equipment, and review of all the sensor data presented in the logs indicates that a permeable

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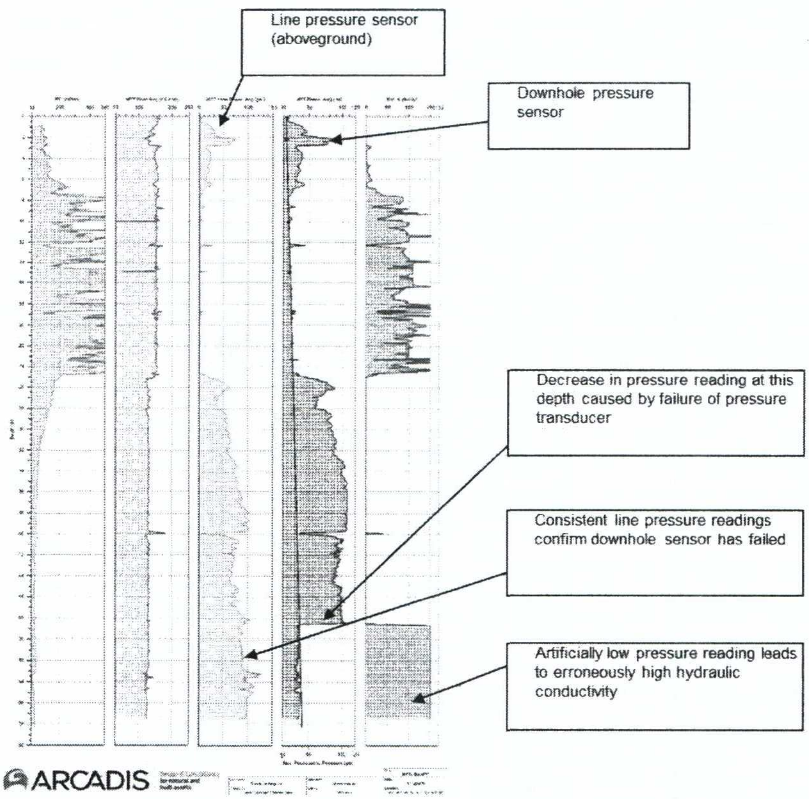
[1] Per 35 IAC 620 110, "Groundwater" means underground water which occurs within the saturated zone and <u>geologic materials</u> where the fluid pressure in the pore space is equal to or greater than atmospheric pressure. [Emphasis added]

unit is not present at the depths in question. When HPT-01, HPT-10, and HPT-10A were completed in 2015, the Arcadis geologist noted that drilling conditions at these locations were more difficult than elsewhere on the Site, leading to greater wear on equipment. In particular, at location HPT-10, the drilling crew noted that the pressure sensor within the drilling tooling failed at a depth of approximately 48 to 49 feet below ground surface (bgs) and required replacement after the boring was complete. A second boring, HPT-10A, was attempted at an adjacent location to obtain more representative pressure data, but a similar sensor failure occurred. The pressure sensor failure resulted in a higher reported estimate of relative hydraulic conductivity on the HPT log, as shown below. The geologist determined that a unit with a higher silt content was present at these locations and depths, which was causing transducer failure and, thus, HPT logs that were not representative of the true geological conditions.

The attribution of this issue to the pressure sensor failure was confirmed through review of the "line pressure" sensor output on the HPT equipment to the downhole pressure reading on the HPT tooling. The line pressure and downhole pressure sensors both track hydrostatic pressure within the water injection line that runs to the downhole injection port, and provide similar relative pressure readings when both sensors are functioning normally. In the case of HPT-01, HPT-10, and HPT-10A, a divergence in the two sensors' output is noted at depth, corresponding to failure of the downhole sensor.

HPT Log



The absence of a higher-permeability unit at these HPT locations is consistent with observations at surrounding boring locations and soil boring logs from piezometer installation.

The properties of the low-permeability, silt and clay deposits encountered during the groundwater investigations at LCCS are consistent with those of the Carmi Member of the Equality Formation, which is a known, regional physiographic feature that has been mapped extensively in the Calumet Region. The low permeability, uniform composition, and significant thickness of this unit provide an effective barrier preventing groundwater from migrating vertically into deeper permeable units. Given the absence of any deposits of the native Dolton Sand at LCCS and the presence of the regional low-permeability silt and clay deposits beneath the fill at the Site, further evaluation of deep groundwater at the Site is not necessary.

Groundwater-Surface Water Interface

Based on suggestions provided by USEPA and IEPA at the October 18, 2017 meeting, the Site Group has further refined the screening evaluations presented in the Tech Memo to determine whether COCs in groundwater emanating from the LCCS could result in exceedances of surface water quality criteria within Indian Ridge Marsh (IRM) The additional refinements involved development of a groundwater to surface water attenuation factor based on groundwater discharge from LCCS surface water flow through IRM, as described below.

The first step in development of the attenuation factor was to determine the flow through IRM. The 1999 Assessment of the Hydrology and Water Quality of Indian Ridge Marsh and the Potential Effects of Wetland Rehabilitation on the Diversity of Wetland Plant Communities (Roadcap et al , 1999) indicates the wetland area of IRM is 92 acres and the mean retention time is 30 days. The stream gauge data presented in Volume V of the Calumet Area Hydrologic Master Plan (V3 Companies, Ltd., 2006) show that the depth of IRM is approximately 2 feet. Together, these values give a flow rate through IRM of 267,000 cubic feet per day (cfd) (43,560 ft^2/acre x 2 feet x 92 acres / 30 days = 267,000 cfd).

The next step was to determine a flow rate of groundwater through the eastern Site boundary. The eastern boundary was divided into six segments with the length of each segment corresponding to frontage for each monitoring well (MW-3 through MW-8). A hydraulic gradient of 0.003 feet per feet (ft/ft) was measured using gauging data and a saturated interval of 4 feet was assumed. Together with the hydraulic conductivities measured for each well during slug tests (slug test logs were submitted with the Tech Memo [Arcadis 2017]), these data were used to calculate flow rates for each of the six segments along the eastern boundary. These flow rates were summed to estimate an overall flow rate for the eastern boundary (approximately 7,500 cfd).

In the third step, an attenuation factor was calculated by dividing the IRM flow rate by the flow rate of the groundwater from LCCS. The attenuation factor is 35.6 (267,000 cfd/7,500 cfd = 35.6). The calculations to develop the attenuation factor are presented in Attachment 1.

When this attenuation factor is applied to the average concentrations of the COCs that exceed surface water benchmarks in site groundwater, all except four COCs have predicted concentrations in IRM surface water below applicable benchmarks (Table 1). Three COCs (*i.e.*, lead, DDT, and toxaphene) exceed one or more aquatic life benchmarks used in the screening evaluation and one (vinyl chloride) exceeds the site-specific recreator benchmark (Table 1). The predicted total lead concentration exceeds the Calumet Open Space Reserve (COSR) background concentration but is less than the COSR surface water Threshold and Benchmark and is also less than both the IEPA and USEPA acute and chronic criteria for protection of aquatic life (Table 1). Thus, while predicted concentrations of lead may exceed possible background concentrations, they are not expected to pose a risk to aquatic life. DDT was not detected in groundwater wells adjacent to the Site boundary. Accordingly, the Site data indicate that DDT is not a COC that is migrating off-site. However, if DDT were assumed to be present at half the detection limit, predicted DDT concentrations exceed the COSR surface water Threshold and COSR benchmarks but are less than USEPA acute and chronic criteria for protection of aquatic life (Table 1). Similarly, toxaphene was not detected in groundwater wells adjacent to the Site boundary but if toxaphene is assumed to be present at half the detection limit, predicted toxaphene concentrations exceed EPA chronic but not acute criteria for protection of aquatic life (Table 1) Because neither DDT nor toxaphene were detected in groundwater and predicted concentrations are below one or more benchmarks for protection of aquatic life, DDT and toxaphene are not expected to pose a risk to aquatic life Concentrations of vinyl chloride are predicted to exceed the site-specific recreator screening benchmark by approximately 2-fold (Table 1). Because the recreator screening benchmarks are based on a target risk of 1×10^{-6}, a more refined evaluation of potential risk will document that potential risks for recreators are well within USEPA's allowable risk range of 1×10^{-6} to 1×10^{-4} and do not pose an unacceptable risk.

Based on these results, combined with those presented in the Tech Memo for other media and relevant benchmarks, the Group believes no additional evaluation or characterization within IRM is necessary

LNAPL at MW-12

LNAPL was observed at MW-12 during the groundwater monitoring events conducted at the Site MW-12 is located near the Paxton Lagoons. The LNAPL may be a remnant from the remediation of those lagoons The lagoons are covered by a cap. The well is screened within waste materials (including paper/pulp, glass, and debris). The LNAPL is present within those waste materials and is not known to extend to surrounding soil. MW-12 is located distant from the eastern boundary of the Site (where groundwater is emanating from the Site) and so is not a direct pathway relevant to potential receptors The Site Group believes that, based on the location of the LNAPL within waste materials, its limited extent, and its distance from potential receptors, no additional characterization or assessment of the LNAPL at MW-12 is necessary.

Proposed Path Forward

Based on the results of the groundwater investigations and the further refined preliminary risk-based screening evaluations presented in the Tech Memo, the Group is prepared to move forward with preparation of the Remedial Investigation (RI) Report, Screening Ecological Risk Assessment Report (SLERA), and Baseline Human Health Risk Assessment (BHHRA). The SLERA will consist of Steps 1 and 2 of USEPA's ecological risk assessment process as described in the August 2015 LCCS RI/FS Work Plan (Arcadis 2015). Consistent with the RI/FS Work Plan, the BHHRA will evaluate potential risks to people who may potentially be exposed to COCs in Indian Ridge Marsh.

A draft version of the RI Report (including the SLERA and BHHRA) will be submitted to the USEPA and IEPA within 120 days following Agency approval to proceed in accordance with the schedule presented in the Statement of Work for the Remedial Investigation and Feasibility Study (SOW) for Operable Unit Two

(OU2). Pursuant to the OU2 SOW, the Draft FS Report would be submitted within 90 days following Agency approval of the RI Report, SLERA and BHHRA.

We trust that this submittal meets your requirements at this time. We look forward to your review, and if you have questions, please do not hesitate to contact Leo Brausch or me.

Sincerely,

Arcadis U.S , Inc.

Jack Kratzmeyer
Certified Project Manager

Paul Anderson, PhD
Principal Scientist

Copies
Paul Lake, IEPA
Susan Franzetti, Nijman Franzetti LLP
LCCS Technical/Steering Committees
Leo Brausch, Brausch Environmental

Enclosures
Tables

1 Screening of Average Attenuated LCCS Groundwater Data Against Applicable Surface Water Benchmarks

Attachments

1 Attenuation Factor Calculation

Table 1. Screening of Average Attenuated LCCS Groundwater Data Against Applicable Surface Water Benchmarks

					Illinois Numeric Water Quality Standards (35 IAC 302.208 and 302.535)						Illinois Numeric Water Quality Standards for the Chicago Area Waterway System (35 IAC 302.407)				Illinois Derived Water Quality Standards (35 IAC 302.210)			
Analyte	CAS	Fraction	Units	Arithmetic Average[1]	Acute Standards for the Protection of Aquatic Organisms	Exceedance (Yes/No)	Chronic Standards for the Protection of Aquatic Organisms	Exceedance (Yes/No)	Standards for Open Waters of Lake Michigan	Exceedance (Yes/No)	Acute Standards for the Protection of Aquatic Organisms	Exceedance (Yes/No)	Chronic Standards for the Protection of Aquatic Organisms	Exceedance (Yes/No)	Acute Standards for the Protection of Aquatic Organisms	Exceedance (Yes/No)	Chronic Standards for the Protection of Aquatic Organisms	Exceedance (Yes/No)
Anions																		
Ammonia Nitrogen	7664-41-7	T	mg/l	7.83	--	--	--	--	15	No	--	--	--	--	--	--	--	--
Metals																		
Arsenic	7440-38-2	D	mg/l	0.00046	0.36	No	0.19	No	--	--	0.34	No	0.15	No	--	--	--	--
Arsenic	7440-38-2	T	mg/l	0.00051	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chromium	7440-47-3	D	mg/l	0.00316	1.3	No	0.44	No	--	--	1.4	No	0.18	No	--	--	--	--
Chromium	7440-47-3	T	mg/l	0.003384	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Iron	7439-89-6	D	mg/l	0.207774	1	No	--	--	--	--	--	--	--	--	--	--	--	--
Iron	7439-89-6	T	mg/l	0.215884	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lead	7439-92-1	D	mg/l	0.001669	0.24	No	0.051	No	--	--	0.24	No	0.051	No	--	--	--	--
Lead	7439-92-1	T	mg/l	0.004446	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mercury	7439-97-6	T	mg/l	0.000009	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Thallium	7440-28-0	D	mg/l	0.000196	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Thallium	7440-28-0	T	mg/l	0.000196	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Vanadium	7440-62-2	D	mg/l	0.000677	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Vanadium	7440-62-2	T	mg/l	0.000758	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Zinc	7440-66-6	T	mg/l	0.006711	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Organochlorine Pesticides																		
4,4-DDD	72-54-8	N	ug/l	0.000914	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4,4-DDE	72-55-9	N	ug/l	0.000914	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4,4-DDT	50-29-3	N	ug/l	0.000914	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Aldrin	309-00-2	N	ug/l	0.000914	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Alpha-BHC	319-84-6	N	ug/l	0.000914	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dieldrin	60-57-1	N	ug/l	0.000914	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Heptachlor	76-44-8	N	ug/l	0.000914	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Heptachlor epoxide	1024-57-3	N	ug/l	0.000914	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Toxaphene	8001-35-2	N	ug/l	0.009144	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Semivolatile Organic Compounds																		
2,4,5-Trichlorophenol	95-95-4	N	ug/l	0.394295	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2,4-Dinitrotoluene	121-14-2	N	ug/l	0.039430	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2-Methyl-4,6-dinitrophenol	534-52-1	N	ug/l	0.794183	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3,3-Dichlorobenzidine	91-94-1	N	ug/l	0.197427	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Anthracene	120-12-7	N	ug/l	0.039709	--	--	--	--	--	--	--	--	--	--	0.66	No	0.53	No
Benzo(a)anthracene	56-55-3	N	ug/l	0.009927	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Benzo(a)pyrene	50-32-8	N	ug/l	0.012947	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Benzo(b)fluoranthene	205-99-2	N	ug/l	0.015352	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Benzo(k)fluoranthene	207-08-9	N	ug/l	0.008781	--	--	--	--	--	--	--	--	--	--	--	--	--	--
bis(2-Chloroethyl)ether	111-44-4	N	ug/l	0.079418	--	--	--	--	--	--	--	--	--	--	--	--	--	--
bis(2-Ethylhexyl)phthalate	117-81-7	N	ug/l	1.834452	--	--	--	--	--	--	--	--	--	--	76	No	17	No
Butyl benzyl phthalate	85-68-7	N	ug/l	0.079418	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dibenzo(a,h)anthracene	53-70-3	N	ug/l	0.012808	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hexachloro-1,3-butadiene	87-68-3	N	ug/l	0.197427	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hexachlorobenzene	118-74-1	N	ug/l	0.019743	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hexachloroethane	67-72-1	N	ug/l	0.197427	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Indeno(1,2,3-cd)pyrene	193-39-5	N	ug/l	0.010543	--	--	--	--	--	--	--	--	--	--	--	--	--	--
N-Nitrosodi-n-propylamine	621-64-7	N	ug/l	0.019743	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pentachlorophenol	87-86-5	N	ug/l	0.794183	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Volatile Organic Compounds																		
Benzene	71-43-2	N	ug/l	2.992170	4200	No	860	No	--	--	4200	No	860	No	3900	No	800	No
Vinyl chloride	75-01-4	N	ug/l	0.119128	--	--	--	--	--	--	--	--	--	--	8400	No	930	No

Notes:

[1] Average calculated using half reporting limit for non-detects. All concentrations divided by 35.76 to account for attenuation.

-- = not available or not applicable

Table 1. Screening of Average Attenuated LCCS Groundwater Data Against Applicable Surface Water Benchmarks

					USEPA Ambient Water Quality Criteria				Calumet Open Space Reserve						Recreator Surface Water Benchmark	
Analyte	CAS	Fraction	Units	Arithmetic Average[1]	Acute Aquatic Life Criteria	Exceedance (Yes/No)	Chronic Aquatic Life Criteria	Exceedance (Yes/No)	Surface Water Background	Exceedance (Yes/No)	Surface Water Threshold	Exceedance (Yes/No)	Surface Water Benchmark	Exceedance (Yes/No)	Benchmark	Exceedance (Yes/No)
Anions																
Ammonia Nitrogen	7664-41-7	T	mg/l	7.83	--	--	--	--	--	--	25	No	140	No	--	--
Metals																
Arsenic	7440-38-2	D	mg/l	0.00046	0.34	No	0.15	No	0.0025	No	0.048	No	0.34	No	0.00969	No
Arsenic	7440-38-2	T	mg/l	0.00051	--	--	--	--	0.0025	No	0.048	No	0.34	No	0.00969	No
Chromium	7440-47-3	D	mg/l	0.00316	1.4	No	0.18	No	< 0.008	No	--	--	--	--	561	No
Chromium	7440-47-3	T	mg/l	0.003384	--	--	--	--	< 0.008	No	--	--	--	--	561	No
Iron	7439-89-6	D	mg/l	0.207774	--	--	--	--	0.71	No	1	No	1	No	126	No
Iron	7439-89-6	T	mg/l	0.215884	--	--	1	No	0.71	No	1	No	1	No	126	No
Lead	7439-92-1	D	mg/l	0.001669	0.21	No	0.0081	No	< 0.002	No	0.0167	No	0.3182	No	--	--
Lead	7439-92-1	T	mg/l	0.004446	--	--	--	--	< 0.002	Yes	0.0167	No	0.3182	No	--	--
Mercury	7439-97-6	T	mg/l	0.000009	--	--	--	--	0.000017	No	0.0009	No	0.0017	No	--	--
Thallium	7440-28-0	D	mg/l	0.000196	--	--	--	--	< 0.002	No	0.01	No	0.02	No	--	--
Thallium	7440-28-0	T	mg/l	0.000196	--	--	--	--	< 0.002	No	0.01	No	0.02	No	--	--
Vanadium	7440-62-2	D	mg/l	0.000677	--	--	--	--	< 0.002	No	0.012	No	0.19	No	0.315	No
Vanadium	7440-62-2	T	mg/l	0.000758	--	--	--	--	< 0.002	No	0.012	No	0.19	No	0.315	No
Zinc	7440-66-6	T	mg/l	0.006711	--	--	--	--	0.012	No	0.3039	No	0.3014	No	55.3	No
Organochlorine Pesticides																
4,4-DDD	72-54-8	N	ug/l	0.000914	--	--	--	--	--	--	--	--	--	--	--	--
4,4-DDE	72-55-9	N	ug/l	0.000914	--	--	--	--	--	--	--	--	--	--	--	--
4,4-DDT	50-29-3	N	ug/l	0.000914	1.1	No	0.001	No	--	--	0.000001	Yes	0.000001	Yes	--	--
Aldrin	309-00-2	N	ug/l	0.000914	3	No	--	--	--	--	--	--	--	--	--	--
Alpha-BHC	319-84-6	N	ug/l	0.000914	--	--	--	--	--	--	--	--	--	--	--	--
Dieldrin	60-57-1	N	ug/l	0.000914	0.24	No	0.056	No	--	--	0.06	No	0.24	No	--	--
Heptachlor	76-44-8	N	ug/l	0.000914	0.52	No	0.0038	No	--	--	0.004	No	0.52	No	--	--
Heptachlor epoxide	1024-57-3	N	ug/l	0.000914	0.52	No	0.0038	No	--	--	0.004	No	0.52	No	--	--
Toxaphene	8001-35-2	N	ug/l	0.009144	0.73	No	0.0002	Yes	--	--	--	--	--	--	--	--
Semivolatile Organic Compounds																
2,4,5-Trichlorophenol	95-95-4	N	ug/l	0.394295	--	--	--	--	--	--	--	--	--	--	--	--
2,4-Dinitrotoluene	121-14-2	N	ug/l	0.039430	--	--	--	--	--	--	--	--	--	--	--	--
2-Methyl-4,6-dinitrophenol	534-52-1	N	ug/l	0.794183	--	--	--	--	--	--	--	--	--	--	--	--
3,3-Dichlorobenzidine	91-94-1	N	ug/l	0.197427	--	--	--	--	--	--	--	--	--	--	--	--
Anthracene	120-12-7	N	ug/l	0.039709	--	--	--	--	--	--	4	No	35	No	3550	No
Benzo(a)anthracene	56-55-3	N	ug/l	0.009927	--	--	--	--	--	--	0.03	No	0.2	No	36.5	No
Benzo(a)pyrene	50-32-8	N	ug/l	0.012947	--	--	--	--	--	--	0.02	No	8.1	No	3.65	No
Benzo(b)fluoranthene	205-99-2	N	ug/l	0.015352	--	--	--	--	--	--	9.1	No	5.7	No	36.5	No
Benzo(k)fluoranthene	207-08-9	N	ug/l	0.008781	--	--	--	--	--	--	--	--	--	--	365	No
bis(2-Chloroethyl)ether	111-44-4	N	ug/l	0.079418	--	--	--	--	--	--	--	--	--	--	11	No
bis(2-Ethylhexyl)phthalate	117-81-7	N	ug/l	1.834452	--	--	--	--	--	--	--	--	--	--	1160	No
Butyl benzyl phthalate	85-68-7	N	ug/l	0.079418	--	--	--	--	--	--	--	--	--	--	433	No
Dibenzo(a,h)anthracene	53-70-3	N	ug/l	0.012808	--	--	--	--	--	--	0.5	No	2.5	No	--	--
Hexachloro-1,3-butadiene	87-68-3	N	ug/l	0.197427	--	--	--	--	--	--	--	--	--	--	--	--
Hexachlorobenzene	118-74-1	N	ug/l	0.019743	--	--	--	--	--	--	--	--	--	--	--	--
Hexachloroethane	67-72-1	N	ug/l	0.197427	--	--	--	--	--	--	--	--	--	--	--	--
Indeno(1,2,3-cd)pyrene	193-39-5	N	ug/l	0.010543	--	--	--	--	--	--	4.3	No	5	No	36.5	No
N-Nitrosodi-n-propylamine	621-64-7	N	ug/l	0.019743	--	--	--	--	--	--	--	--	--	--	--	--
Pentachlorophenol	87-86-5	N	ug/l	0.794183	19	No	15	No	--	--	--	--	--	--	0.866	No
Volatile Organic Compounds																
Benzene	71-43-2	N	ug/l	2.992170	--	--	--	--	--	--	--	--	--	--	--	--
Vinyl chloride	75-01-4	N	ug/l	0.119128	--	--	--	--	--	--	--	--	--	--	0.056	Yes

Notes:

[1] Average calculated using half reporting limit for non-detects. All concentrations divided by 35.76 to account for attenuation.

-- = not available or not applicable

DRAFT

ARCADIS Design & Consultancy for natural and built assets

Indian Ridge Marsh Flow Rate[1]		
Area	92	acres
Average Depth	2	feet
Retention Time	30	days
Flow Rate (Q)	**267,168**	**ft^3/day**
LCCS Eastern Boundary Discharge Rate[2]		
Average Saturated Thickness (b)	4	feet
Hydraulic gradient (i)	0.003	feet/feet
MW-3		
Hydraulic conductivity (K)	700	feet/day
Discharge Front Length (L)	89	feet
Flow Rate (Q)	**748**	**ft^3/day**
MW-4		
Hydraulic conductivity (K)	5.8	feet/day
Discharge Front Length (L)	348	feet
Flow Rate (Q)	**24**	**ft^3/day**
MW-5		
Hydraulic conductivity (K)	480	feet/day
Discharge Front Length (L)	540	feet
Flow Rate (Q)	**3,110**	**ft^3/day**
MW-6		
Hydraulic conductivity (K)	400	feet/day
Discharge Front Length (L)	477	feet
Flow Rate (Q)	**2,290**	**ft^3/day**
MW-7		
Hydraulic conductivity (K)	330	feet/day
Discharge Front Length (L)	324	feet
Flow Rate (Q)	**1,283**	**ft^3/day**
MW-7		
Hydraulic conductivity (K)	11	feet/day
Discharge Front Length (L)	128	feet
Flow Rate (Q)	**17**	**ft^3/day**
Total Flow Rate (Q)	**7,472**	**ft^3/day**
Mixing Factor	**35.76**	

$$Q = K * L * b * i$$

$$Mixing\ Factor = \frac{IRM\ FlowRate}{LCCS\ Discharge\ Factor}$$

Notes:

[1]Reference is Roadcap, G.S., Wenzel, M.B., Lin, S.D., Herricks, E.E., Raman, R.K., Locke, R.L., Hullinger, D.L. 1999. An Assessment of the Hydrology and Water Quality of Indian Ridge Marsh and the Potential Effects of Wetland Rehabilitation on the Diversity of Wetland Plant Communities, December.

[2]The hydraulic gradient was measured from the March 2016 piezometer gauging data. The hydraulic conductivities were determined during slug tests in July 2016. Data is available in the 2017 Technical Memorandum prepared by Arcadis.